Jet Propulsion Laboratory
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ECOSTRESS Calibration and Validation

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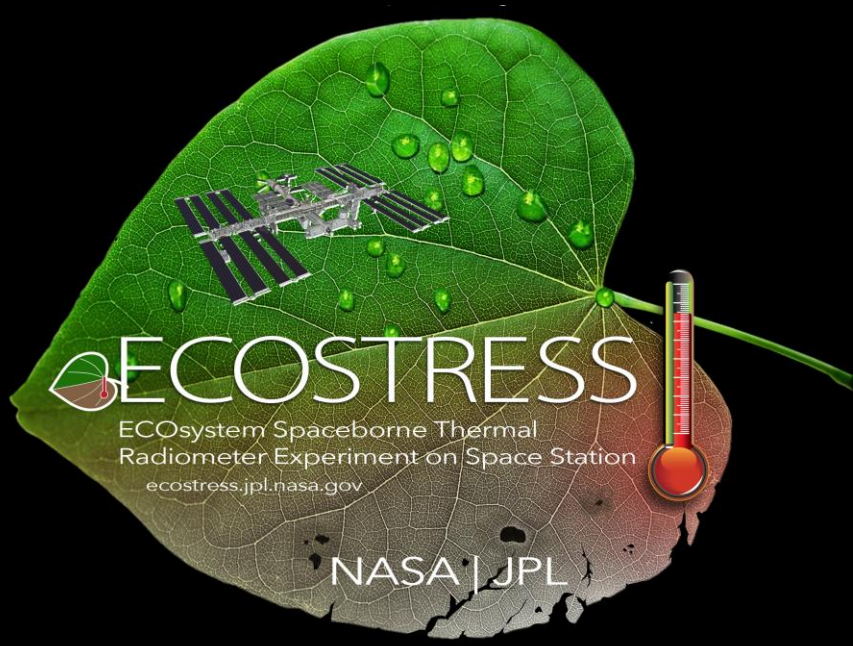


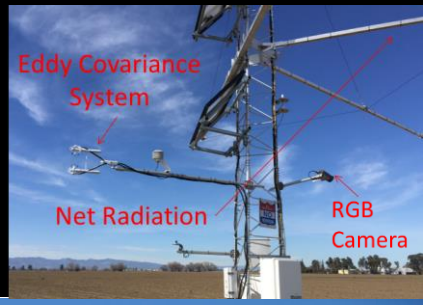
Outline

- JPL Field Sites
- FLUXNET
- Input variables
- Data ingestion
- Closing

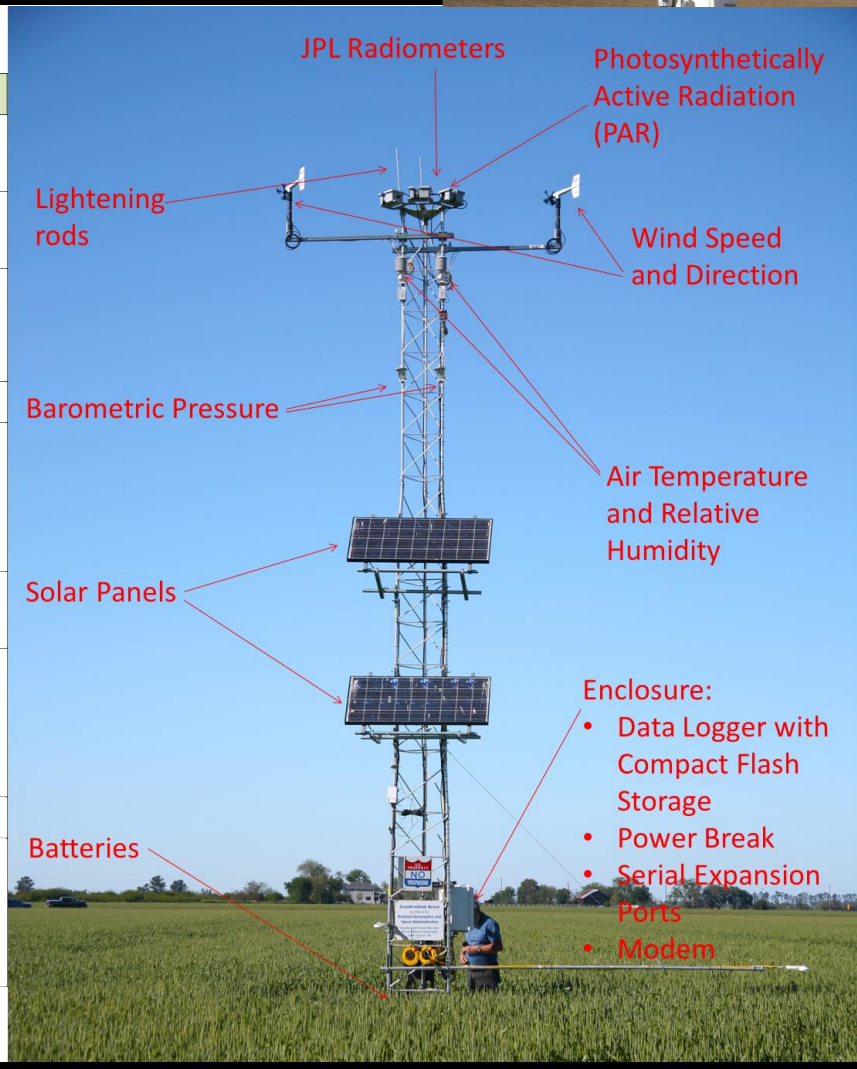
JPL Field Sites – Lake Tahoe and Salton Sea

- Permanently moored measurement stations that measure the bulk and radiometric temperature of the water bodies every two minutes.
- Lake Tahoe CA/NV is high (small atmospheric correction) and large (~35x20km)
- Salton Sea is low (large atmospheric correction)
- Both sites are homogenous and available year round
- JPL has developed very accurate radiometers (<50 milli-kelvin) to measure the surface radiometric temperature for validation
- These are the only automated mid and thermal infrared calibration and validation sites in the world.

JPL Field Sites – Russell Ranch



Instrument/Sensor Description	Data Collected
Wind speed indicator (MET)	The values are in counts and are converted to meters per second (ms^{-1})
Wind direction indicator (MET)	The values are in counts and are converted to degrees with respect to magnetic north
Air Temperatures with Gill radiation shield (MET)	The values are in counts and are converted to degrees Celsius (the air temperatures and relative humidity sensor are integrated together)
Relative Humidity (RH) (MET)	The values are in counts and are converted to percent
Barometric Pressure with Pressure Port (MET)	The values are in counts and are converted to hectopascals or millibars (hPa or mBar). The pressure port is used to prevent any errors in pressure due to wind over the sensor
Li-COR Photosynthetically Active Radiation (PAR) sensor	Sensor measures Photosynthetic Photon Flux Density (PPFD) in both natural and artificial light
Net Radiometer	Incoming solar radiation (short wave), reflected solar radiation, incoming far infrared radiation (long wave), outgoing far infrared radiation, sky temperature and ground temperature
JPL-built Radiometer	Land surface temperature
Eddy Covariance System	Air temperature, sonic air temperature, barometric pressure, absolute carbon dioxide and water vapor densities and the orthogonal wind components (three-dimensional)



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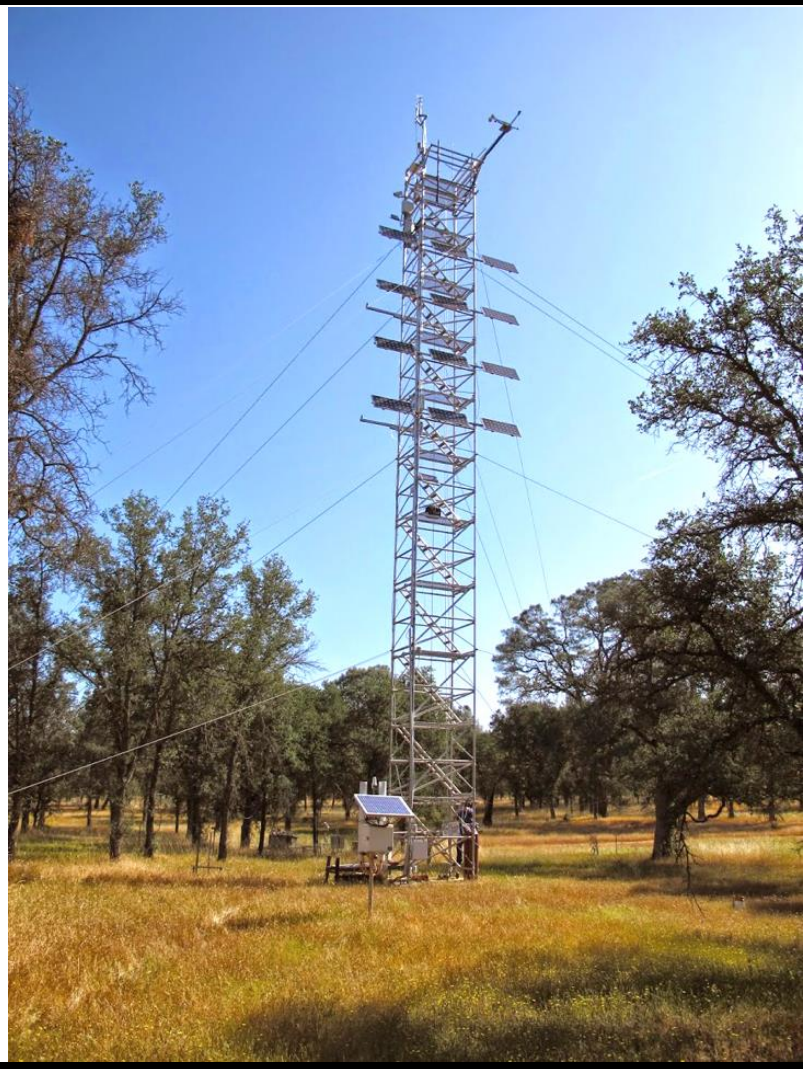
FLUXNET Sites

FLUXNET, known as a “network of regional networks” is a freely available database of observations from micrometeorological tower sites (fluxnet.fluxdata.org). Eddy covariance measurements are routinely made within more than 800 sites spanning most of the world’s climate zones and biomes in North, Central and South America, Europe, Asia, Africa, and Australia. The eddy covariance measurements of carbon dioxide and water vapor exchange are important variables for the validation of evapotranspiration. Typically sites provide: skin temperature or upwelling/downwelling longwave fluxes, latent heat flux, Gross Primary Productivity (GPP), net radiation and air temperature. The FLUXNET site shown (right) is Tonzi Ranch, located in the foothills of the Sierra Nevada Mountains.



FLUXNET

L2(LSTE)	**LAND SURFACE TEMPERATURE**	LW_U
L3(ET_PT-JPL) L3(ET_ALEXI)	**EVAPOTRANSPIRATION**	*LE*
L4(WUE)	**WATER USE EFFICIENCY**	*LE/GPP*

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Requested Variables

Parameter/Variable	Shorthand (Desired units)
TIME_START	YYYYMMDDhhmm
TIME_END	YYYYMMDDhhmm
Latent Heat Flux	LHF (W m^{-2})
Latent Heat Flux Quality Flag	LHF_qc (-)
Sensible Heat Flux	SHF (W m^{-2})
Sensible Heat Flux Quality Flag	SHF_qc (-)
Ground Heat Flux	GHF (W m^{-2})
Ground Heat Flux Quality Flag	GHF_qc (-)
Gross Primary Productivity	GPP (g C m^{-2} s^{-1})
Gross Primary Productivity Quality Flag	GPP_qc (-)
Air Temperature above Canopy	Ta (°C)
Air Temperature above Canopy Quality Flag	Ta_qc (-)
Air Temperature at 2 m	T2 (°C)
Air Temperature at 2 m Quality Flag	T2_qc (-)
Vapor Pressure Deficit	VPD (kPa)
Vapor Pressure Deficit	VPD_qc (-)
Net radiation	Rn (W m^{-2})
Net radiation quality flag	Rn_qc (-)
Incoming Shortwave Radiation	RdS (W m^{-2})
Incoming Longwave Radiation	RdL (W m^{-2})
Outgoing Shortwave Radiation	RuS (W m^{-2})
Outgoing Longwave Radiation	RuL (W m^{-2})
Photosynthetic Active Radiation	PAR (umol m^{-2} s^{-1})
Barometric pressure	PRESS (kPa)
Precipitation	PREC (mm hh^{-1})
Relative Humidity	Rh (%)
Wind Speed	Wspd (m s^{-1})
Wind Direction	Wdir (degrees)
Soil Temperature	Ts (°C)
Soil Moisture	SWC (% volumetric)

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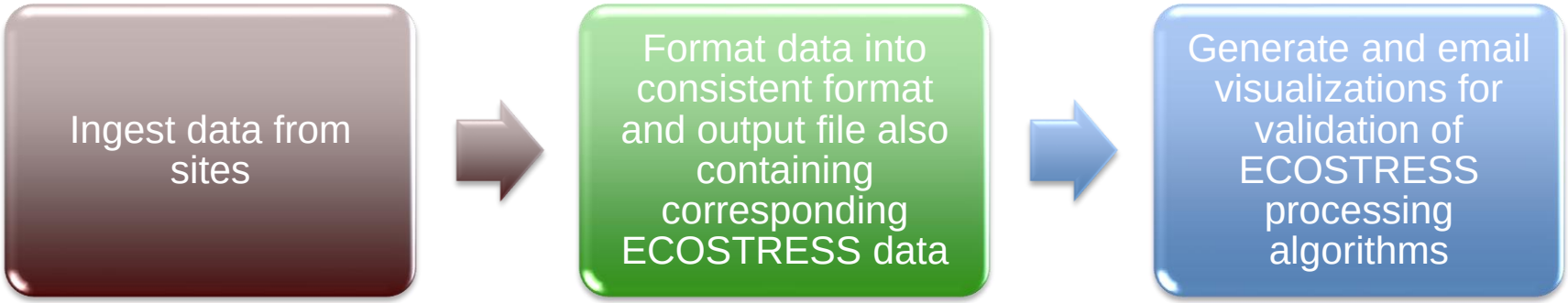
Goals

- Develop a Cal/Val infrastructure for ECOSTRESS
  - **DI**: Data Ingestion
  - **DDM**: Data Diagnostics and Matchup
  - **DVV**: Data Validation Visualization

- Automated!



Progress towards those goals

- >100 flux tower PIs were contacted
- ~70 showed initial interest
- ~40 sites have responded and shared sample data
- Ongoing discussions/negotiations
- Letters of support are being generated
- Ingestion and formatting functionality has been designed

Data Ingestion

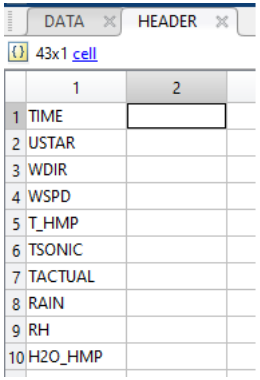
- Data storage mechanisms vary, and data is currently ingested from:
  - FPT
  - Dropbox
  - HTML
- Data upload times vary, from instantaneous capture, to 3 month turnaround

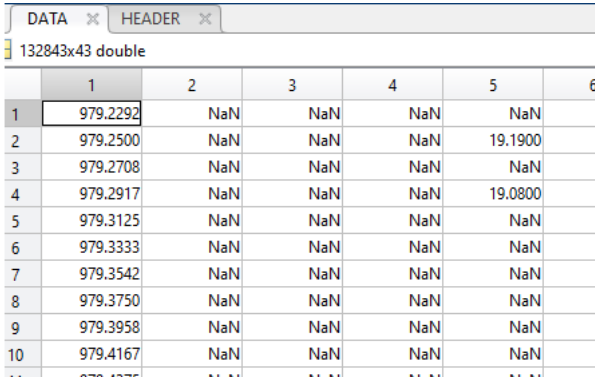
Data Diagnostics and Matchup

- Purpose:
  - Output formatted data containing the relevant variables
    - Format all site data into a consistent format
    - Ingest ECOSTRESS data and match up (spatially/temporally) with in situ data
  - (Handle/log any within-site inconsistencies)

year,doy,hhmm,shf1,shf2,PREC,Ta,VPD,Rn,RdS,RdL,RuS,RuL,Rh,T2,PRESS,Ts
2016,227,0000,-29.98,-22.55,0,25.84,2503.31,-84.72,-1.6,321.92,3.13,416.46,24.8
2016,227,0030,-30,-23.15,0,25,2329.01,-83.91,-2.3,319.35,2.4,413.02,26.47,19.64
2016,227,0100,-29.98,-23.71,0,24.91,2307.39,-598524.73,-699900,-679099.35,-7
2016,227,0130,-29.83,-24.21,0,24.12,2147.87,-598528.44,-699900,-679104.61,-7
2016,227,0200,-29.37,-24.62,0,24.42,2199.12,-81.18,-0.5,317.45,3.54,408.43,28.1
2016,227,0230,-29.39,-24.89,0,24.36,2184.52,-80.73,-1.2,316.98,3.33,407.45,28.3
2016,227,0300,-29.19,-25.12,0,24.41,2190.77,-78.86,-1.4,316.57,3.13,405.8,28.35
2016,227,0330,-28.71,-25.35,0,24.77,2258.8,-598523.68,-699900,-679102.51,-72
2016,227,0400,-28.48,-25.54,0,24.37,2181.56,-73.97,-1.5,317.8,2.92,402.45,28.48
2016,227,0430,-28.09,-25.7,0,24.22,2155.36,-69.46,-0.4,320.46,3.02,401.22,28.7,
2016,227,0500,-27.65,-25.75,0,23.38,2005.94,-66.84,-2,320.81,2.4,397.57,30.2,15
2016,227,0530,-26.98,-25.71,0,22.43,1849.18,-64.6,2.9,319.83,3.33,396.84,31.84
2016,227,0600,-24.26,-25.46,0,22.64,1890.52,-598536.35,-699900,-679116.96,-7
2016,227,0630,-19.51,-24.38,0,23.88,2109.1,-12.18,96.9,324.46,28.65,414.96,28.

	JD	Year	Month	Day	Hour	Dtime	FC	FS	UST	LE	LE_gap
							umol/m2/	umol/m2/	m/s	W/m2	W/m2
7	1	2013	1	1	30	1.0208	0.52	0	0.108	-3.7	-3.
8	1	2013	1	1	130	1.0625	-0.03	0	0.122	-2.4	-2.
9	1	2013	1	1	230	1.1042	0.29	0	0.114	-1.8	-1.
10	1	2013	1	1	330	1.1458	0.36	0	0.095	-1.9	-1.
11	1	2013	1	1	430	1.1875	0.03	0.2	0.052	-0.7	-0.
12	1	2013	1	1	530	1.2292	3.24	0.1	0.046	-4	-
13	1	2013	1	1	630	1.2708	0.16	0.1	-9999	-0.2	-0.
14	1	2013	1	1	730	1.3125	-0.32	0.1	-9999	2.4	2.
15	1	2013	1	1	830	1.3542	-0.54	0.1	0.012	-9999	4.
16	1	2013	1	1	930	1.3958	-0.27	-0.2	-9999	-9999	6.
17	1	2013	1	1	1030	1.4375	-0.23	-0.3	0.075	2.3	2.
18	1	2013	1	1	1130	1.4792	0.25	-0.2	0.063	7.2	7.
19	1	2013	1	1	1230	1.5208	0.31	-0.1	0.11	9.1	9.
20	1	2013	1	1	1330	1.5625	0.43	-0.1	0.131	7.7	7.
21	1	2013	1	1	1430	1.6042	0.4	0	0.103	6.5	6.
22	1	2013	1	1	1530	1.6458	0.09	0	0.142	4.4	4.
23	1	2013	1	1	1630	1.6875	-0.47	0	-9999	-9999	-2.

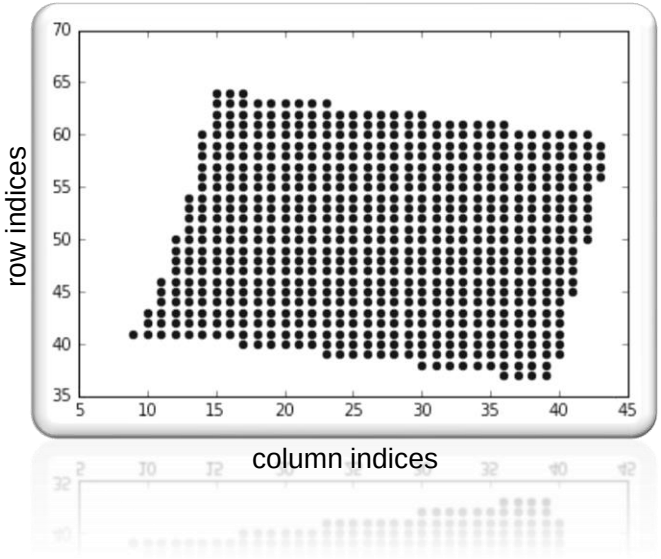




Data Diagnostics and Matchup

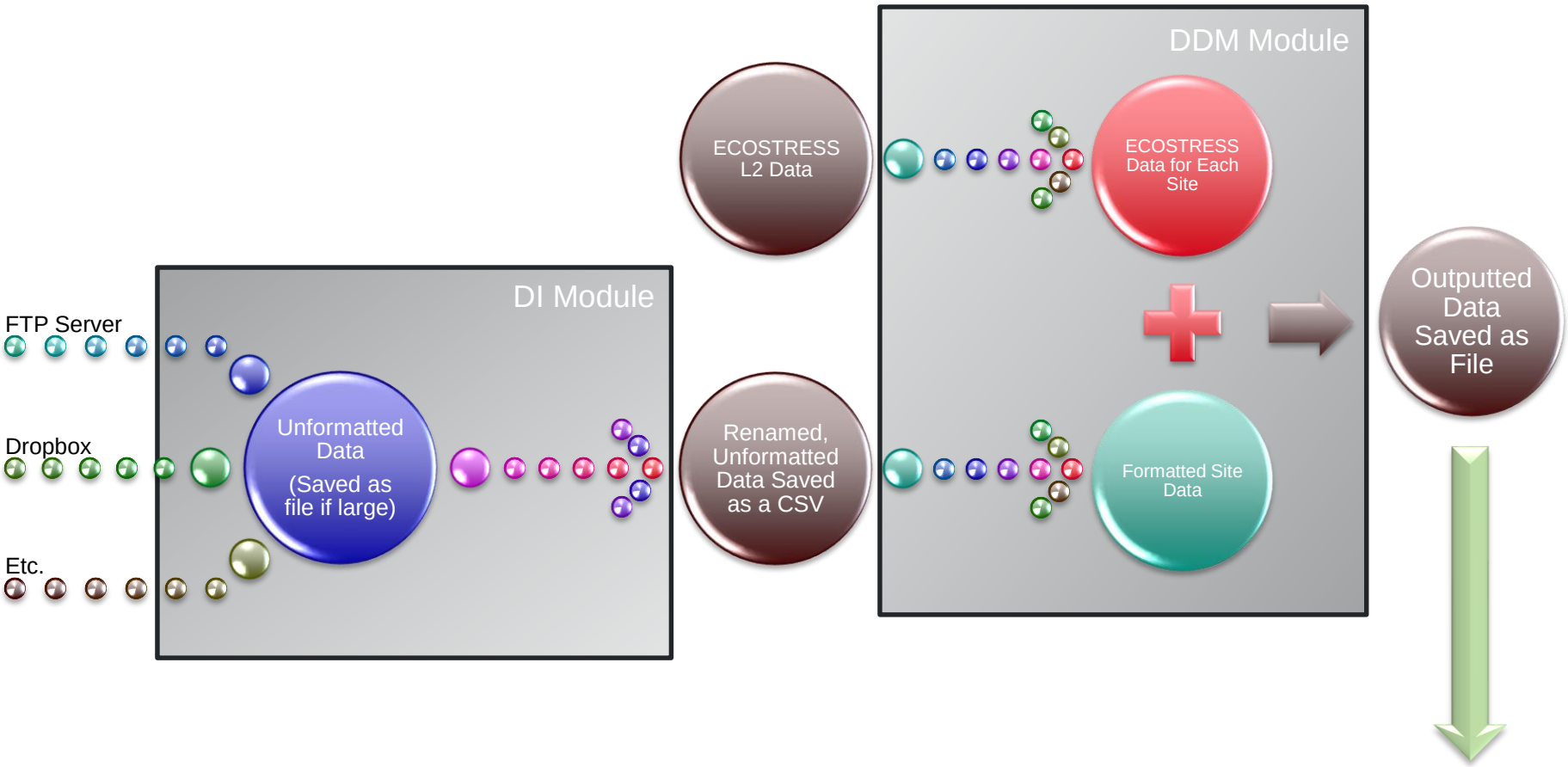
- Finding the ECOSTRESS swath in which to search
  - Will incorporate a package that returns the swaths containing a given location

- Finding pixels (~70 m^2) in rectangular site footprints (~1 km^2)

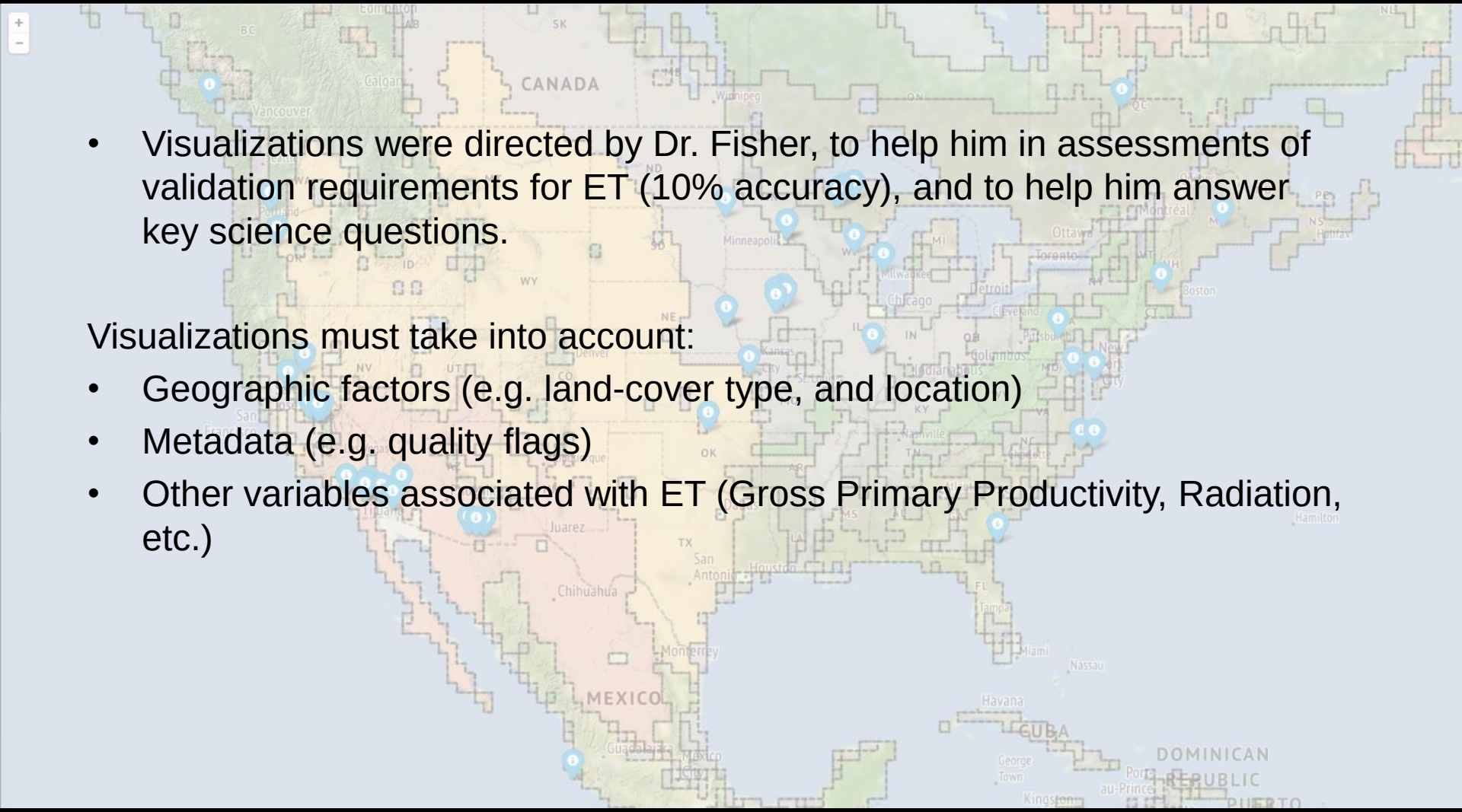


- Sample L2 data has ~10^7 pixels per swath
  - Nearest-neighbor search for center of footprint
  - Flood-fill to find all pixels inside the footprint
  - Average ECOSTRESS data over the footprint

Data Ingestion/Data Diagnostics and Matchup



Data Visualization

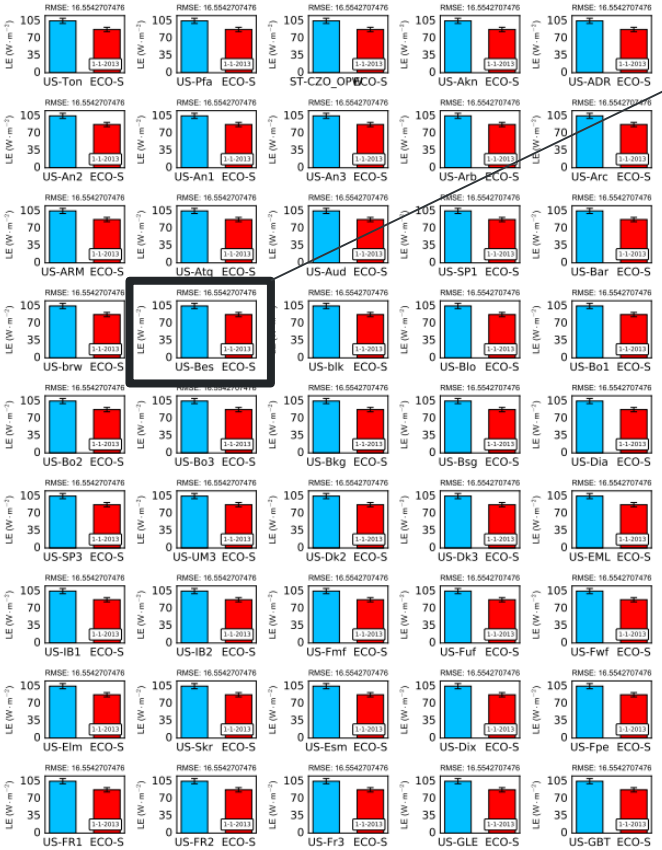


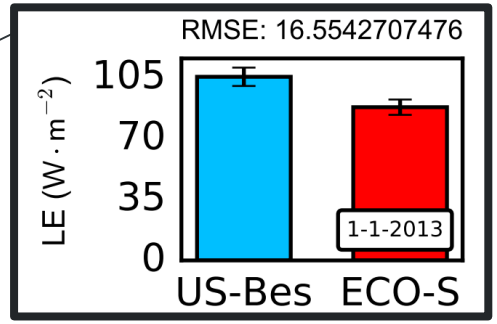
- Visualizations were directed by Dr. Fisher, to help him in assessments of validation requirements for ET (10% accuracy), and to help him answer key science questions.

Visualizations must take into account:

- Geographic factors (e.g. land-cover type, and location)
- Metadata (e.g. quality flags)
- Other variables associated with ET (Gross Primary Productivity, Radiation, etc.)

Data Visualization





Quick-look Table #1

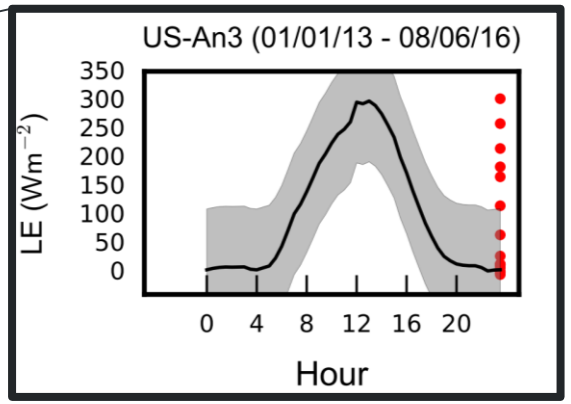
Compares ECOSTRESS data against site average, on a per site basis, each day.

Color based on percent difference

→ <10%

→ >10%

Data Visualization

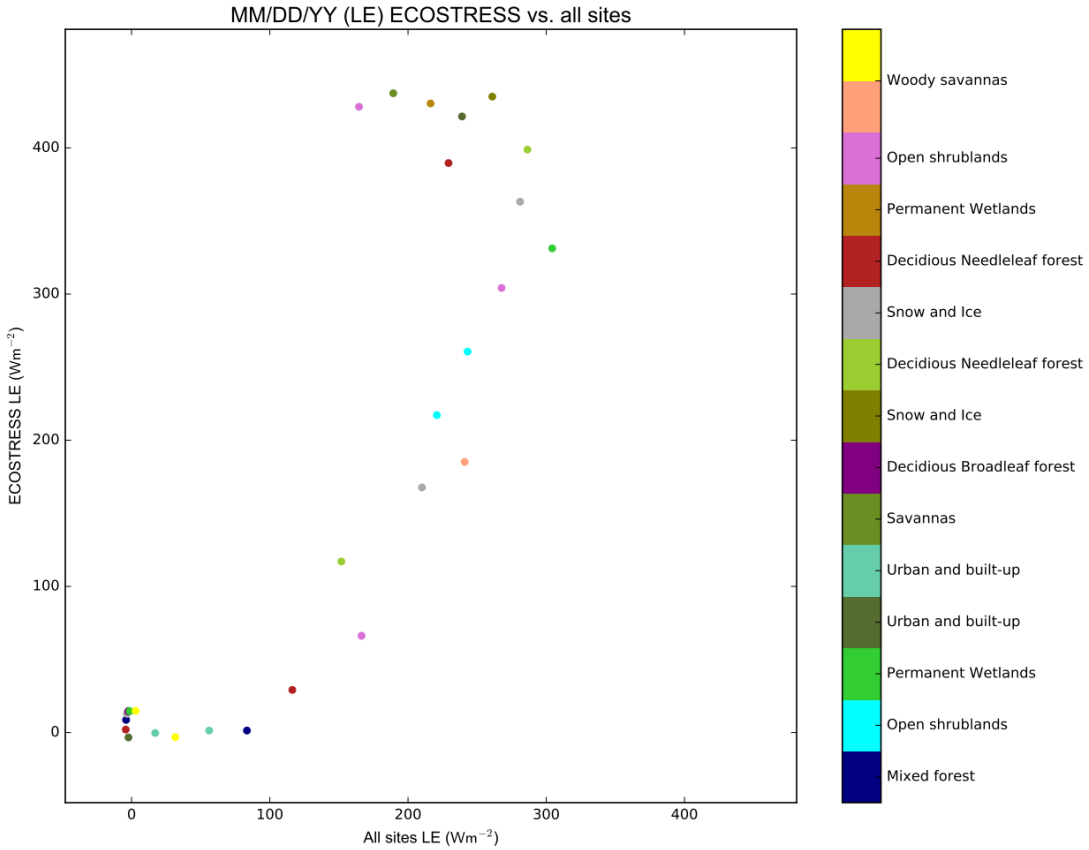


Quick-look Table #4

Compares **2 months** of ECOSTRESS data versus the half-hourly average of site data.

Red points indicate ECOSTRESS data, gray shading indicates standard deviation region.

Data Visualization

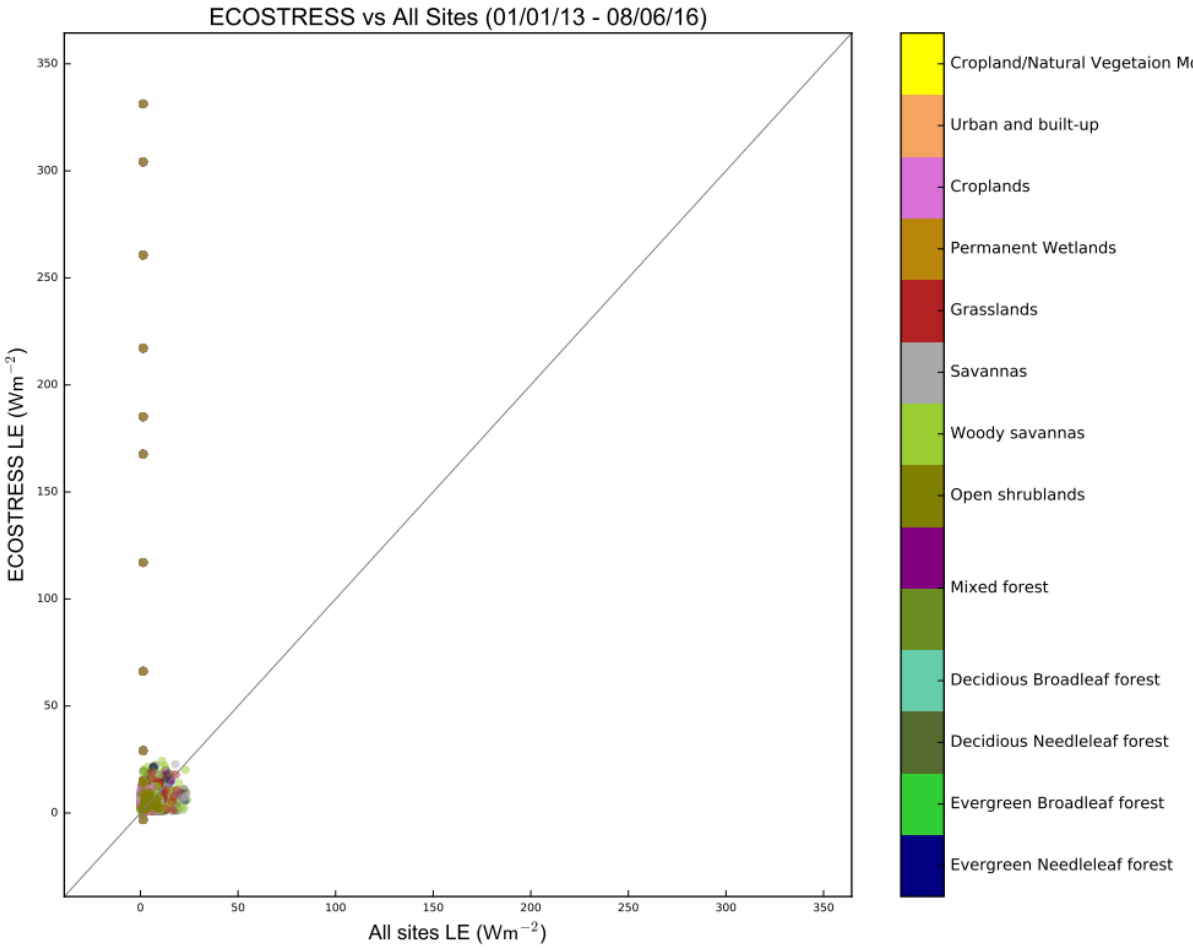


Cumulative daily comparison

Compares 1 day of ECOSTRESS data versus all sites' measurements for that day.

Color is based on landcover.

Data Visualization

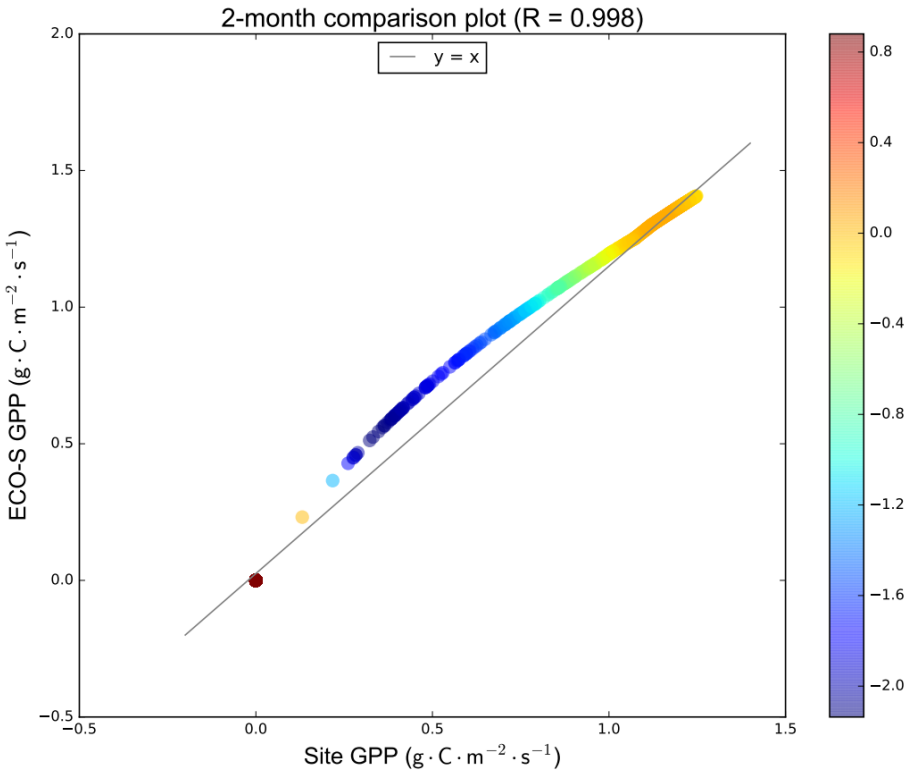


Cumulative bimonthly comparison

Compares **2 months** of ECOSTRESS data versus all sites' measurements for that time period.

Color is based on landcover.

Data Visualization



Color indicates density computed from KDE (log-density)

Data Visualization

ECOSTRESS Report -- (Tue Aug 16, 2016)

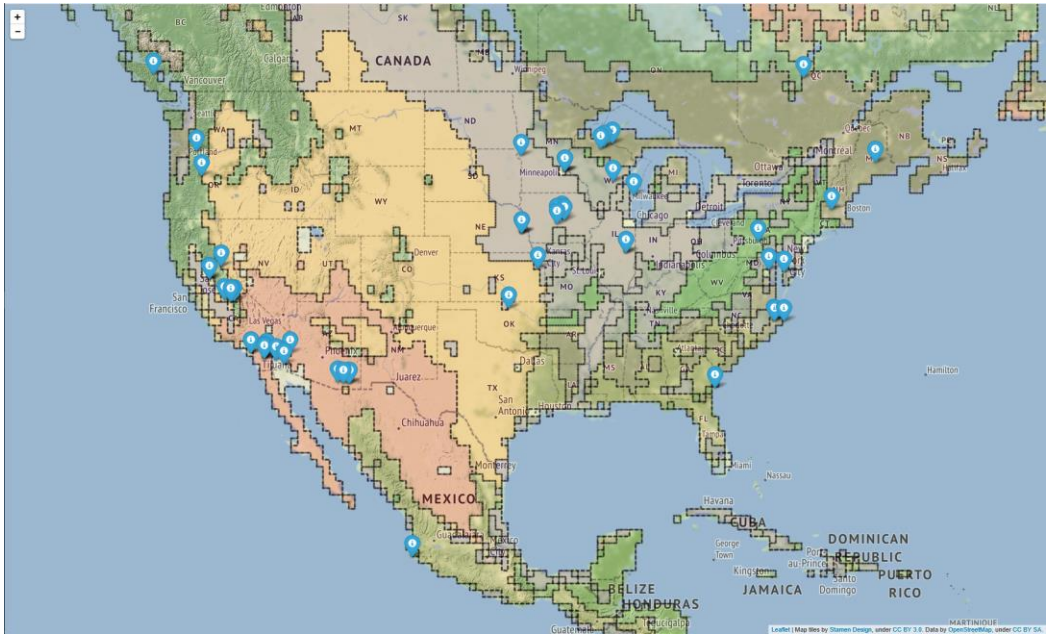
91 new files were found for today.

Site Name	Site Avg GPP	ECO-S GPP	RMSE (GPP)	Site ET	ECO-S ET	RMSE (ET)	Data Loss (%)
US-Ton	6.303	2.17	nan	105.484	88.022	nan	39.72
US-Pfa	6.303	2.17	nan	105.484	88.022	nan	39.72
ST-CZO_OPW	6.303	2.17	nan	105.484	88.022	nan	39.72
US-Akn	6.303	2.17	nan	105.484	88.022	nan	39.72
US-ADR	6.303	2.17	nan	105.484	88.022	nan	39.72
US-An2	6.303	2.17	nan	105.484	88.022	nan	39.72
US-An1	6.303	2.17	nan	105.484	88.022	nan	39.72
US-An3	6.303	2.17	nan	105.484	88.022	nan	39.72
US-Arb	6.303	2.17	nan	105.484	88.022	nan	39.72
US-Arc	6.303	2.17	nan	105.484	88.022	nan	39.72
US-ARM	6.303	2.17	nan	105.484	88.022	nan	39.72
US-Atq	6.303	2.17	nan	105.484	88.022	nan	39.72
US-Aud	6.303	2.17	nan	105.484	88.022	nan	39.72
US-SP1	6.303	2.17	nan	105.484	88.022	nan	39.72
US-Bar	6.303	2.17	nan	105.484	88.022	nan	39.72
US-brw	6.303	2.17	nan	105.484	88.022	nan	39.72
US-Bes	6.303	2.17	nan	105.484	88.022	nan	39.72

Statistics report

Compute averages, RMSE, and data loss percentage on a per site basis.

Data Visualization



Interactive map

Map delivered through HTML – shows geographic location of sites, with MODIS land cover overlay.

Factors: Landcover data (color of tile), comparison metric (would be for color of the dot)

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Closing

- Flux tower data has been sourced globally
- A mechanism has been designed to:
  - Automatically ingest data from different sources
  - Convert data to a consistent format
  - Provide visualizations for easy data monitoring
- These will enable calibration and validation of ECOSTRESS L2 and L3 products over a variety of biomes

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